Assessing Team Member Citizenship in Capstone Engineering Design Courses*

DENNY DAVIS
Engineering Education Research Center and the Voiland School of Chemical Engineering and Bioengineering, Washington State University, Pullman, WA 99164–2710 USA. E-mail: davis@wsu.edu

MICHAEL TREVISAN
Learning and Performance Research Center and the Department of Educational Leadership and Counseling Psychology, Washington State University, Pullman, WA 99164–2136 USA. E-mail: trevisan@wsu.edu

ROBERT GERLICK
Engineering Education Research Center, Washington State University, Pullman, WA 99164–2714 USA. E-mail: robgerlick@yahoo.com

HOWARD DAVIS
Voiland School of Chemical Engineering and Bioengineering, Washington State University, Pullman, WA 99164–2710 USA. E-mail: davish@wsu.edu

JAY MCCORMACK
Mechanical Engineering Department, University of Idaho, Moscow, ID Moscow, ID 83844–0902 USA. E-mail: mccormack@uidaho.edu

STEVEN BEYERLEIN
Mechanical Engineering Department, University of Idaho, Moscow, ID Moscow, ID 83844–0902 USA. E-mail: sbeyer@uidaho.edu

PHILLIP THOMPSON
Civil and Environmental Engineering, Seattle University, Seattle, WA 98122–4340 USA. E-mail: Thompson@seattleu.edu

SUSANNAH HOWE
Picker Engineering Program, Smith College, Northampton, MA 01062 USA. E-mail: showe@email.smith.edu

PAUL LEIFFER
Electrical Engineering, LeTourneau University, Longview, TX 75605 USA. E-mail: paulleiffer@letu.edu

PATRICIA BRACKIN
Mechanical Engineering Department, Rose-Hulman Institute of Technology, Terre-Haute, IN 47803 USA. E-mail: patricia.brackin@rose-hulman.edu

Capstone engineering design courses exhibit a universal need to improve student teamwork performance while also documenting student teamwork achievements. To meet this need, the Transferable Integrated Design Engineering Education (TIDEE) consortium developed assessment instruments and companion scoring rubrics to target teamwork achievement in four areas: team relationships, joint work, individual work, and information management. Desired attributes of these instruments included transferability, practicality, reliability, user satisfaction, and robustness. Transferability was addressed by grounding the instruments in the teamwork literature and developing, piloting, and refining their use at multiple universities. A web interface for deploying and scoring the assessment instruments has supported sustainable, practical application of the instruments in a classroom setting as well as enabled design education research.

This paper describes initial deployment and pilot testing of one of the teamwork assessments—Team Member Citizenship. This assessment is unique from other developers' teamwork assessments in its combined features of: (1) being part of an integrated package of assessments for teamwork, (2) having a strong focus on reflective practice within teamwork, (3) having been tested for inter-rater reliability in scoring, (4) enabling faculty and peer feedback that supports students' growth in teamwork, and (5) providing data useful for grading and program assessment. Results demonstrate that this assessment provides data consistent with expectations, has reliability across rater scoring, and exhibits high levels of perceived value by student and faculty users. The teamwork assessments compile readily accessible research data about students' perceptions and performance of teamwork in design project environments. Additional assessment testing and data analysis are needed to further establish instrument validity and reliability.

Keywords: teamwork assessment; team performance; peer review; formative assessment

1. INTRODUCTION

ENGINEERING PROGRAMS use capstone engineering design courses as a site for assessing several of the ABET (engineering accreditation agency in USA, formerly named Accreditation Board for Engineering and Technology) professional outcomes, one of which is teamwork [1]. Capstone course instructors often express concerns about their abilities to teach and assess this type of outcome [2]. Additionally, research findings on how students learn [3] and how we know what students have learned [4] are not well connected with the instructional strategies and assessment methods in many engineering courses, including capstone design. The Transferable Integrated Design Engineering Education (TIDEE) consortium of institutions seeks to better monitor professional skills development and help engineering educators bridge the gap between educational theory and classroom practice in capstone engineering design courses [5].

TIDEE's overall focus is developing and assessing students' capabilities in engineering design, including teamwork. To this end, project faculty have developed and pilot tested an integrated set of assessments for teamwork, professional development, design processes, and solution assets [6]. To date, they have created and implemented three formative teamwork assessments that provide timely feedback to students regarding individual team skills and overall team performance. They have also developed and used one summative assessment that provides both individual and team data useful for course grading and documenting student performance in teamwork. All four assessment instruments probe teamwork achievement in four areas: team relationships, joint work, individual work, and information management. A key feature of the assessments is a web-based implementation that allows instructors to use the assessments in a manner that supports student reflection, is sustainable, and minimizes non-value-added activity. Unlike other web-based teamwork assessment systems, the TIDEE system captures written observations, insights, and recommendations from multiple users to guide improvement. The system permits the instructor to make assignments to individual students, teams of students, or the entire class. These assessments also allow the instructor to gather evidence of students' metacognition regarding teamwork and their perceptions of themselves and their peers.

This paper provides an overall description of the four TIDEE teamwork assessments, with more detailed description and results from implementation of one formative assessment instrument (Team Member Citizenship) in capstone design courses. Background on teamwork assessment is reviewed, followed by a description of the Team Member Citizenship assessment instrument and scoring rubrics. Results are reported from analyses of student work, student and faculty surveys, and inter-rater reliability studies for the 2008–2009 academic year.

2. LITERATURE REVIEW

It is generally accepted that teamwork is an important skill in engineering design practice [7] and is a common element of the engineering experience in industry [8, 9]. Despite the consistent occurrence of teamwork in engineering practice and the high quality products resulting from well functioning teams, design teamwork teaching and learning could be much better integrated into engineering curricula [10–12]. Research conducted in numerous types of team environments can be used to guide improvement of teamwork skills in engineering graduates while simultaneously enhancing their team experiences in engineering design courses [13, 14]. Three focuses of the TIDEE collaborators have included defining measures of team skills, using self and peer assessment to apply these measures to enrich formative assessment of teamwork, and web-based tools that enable efficient integration of team skills assessment into engineering project experiences.

Assessing team performance requires criteria against which the quality of an individual's team skills can be measured. Taggar and Brown [15] developed a list of team member behaviors in problem solving environments that encompassed prior related work [16–19]. The list can be used to classify effectiveness of a team member across fourteen dimensions. Furthermore, Rosenstein and Dickinson [20] created a tool for measuring team effectiveness based on 87 elements. Wheelan [5] created a list of characteristics to guide behavior of team members and team leaders needed to build high performing teams.

In order to apply measurements of team skill, both peer and self-assessment have been proposed, tested, and found to be effective in engineering, design, and teamwork settings. Topping [20] reviewed the literature on the modes, value, and reliability of peer assessment. He reported that the results of peer assessment were typically as good or exceeded instructor results. In engineering design teamwork, he highlighted a successful use of peer assessment in which team members defined the assessment criteria and performed regular peer assessment to assign grades. He also discussed early efforts at using computers to enhance peer assessment either as a means for delivering the assessment or as a means for sharing the content to be assessed.

Agogino et al. [22] showed that teamwork assessment by peers at the midpoint of a project coupled with instructor guidance effectively influenced the performance of a team. Based on their research, Agogino et al. suggested that educators leverage peer evaluation to gain insights into team performance and progress in design activities. Hirsch and McKenna [23] analyzed teaching and

learning methods to combine reflective thinking with teamwork experiences. Their findings corresponded with others [24, 25] who have found that the use of reflection in design projects can provide students insights on teamwork.

2.1 Web-based tools for assessing teamwork

Loughry et al. [26] described the development and testing of the Comprehensive Assessment of Team Member Effectiveness (CATME) instrument for use in peer evaluation and self-evaluation of teamwork skills. Teamwork skills were classified into five categories explored through a series of questions in which the user rates each team member on a Likert scale. A short form of the instrument [27] asks users to choose a single group of descriptive statements from an ordered list of five groups of characteristics. Thus, user input was reduced from 87 Likert scale responses to five responses, one for each category. The CATME instrument can be used online through a web interface [28] that enables teammates to rate each other anonymously and through which instructors can view the results and statistical analysis of the results. The CATME instrument is proposed to guide team improvement, measure past performance, or act as a framework for new teams to discuss elements of teamwork.

4-D Systems [29] produced a commercial tool aimed at improving an individual's team performance through a web survey of past or current colleagues. The concept upon which this tool is constructed is derived from work by NASA [30]. The survey questions direct the respondent to rate the frequency of different behaviors on a seven-point scale, ranging from 'always exhibiting the behavior' to 'never exhibiting the behavior.' Responses from multiple respondents are compiled into a report that presents a graphical distribution of responses, a temporal tracking of responses, and recommended improvements based on noted areas of weakness.

Merits of web-based assessments make web implementation an essential feature of any assessment intended for wide adoption. Web-based implementation offers potential for digital handling of student and instructor responses, which facilitates efficient information sharing among team members and multiple instructors. Data from multiple respondents can also be compiled and analyzed to identify similarities, differences, and trends. Peer feedback to students can be kept anonymous to other students. For these and additional reasons, TIDEE's teamwork assessments are implemented in web-based format. One commonality between the TIDEE teamwork assessment and these other web-based assessments of teamwork is the use of Likert scale-based questions. However, the primary difference is the use of short, reflective essays that complement and enrich the interpretation of the scaled data.

3. TIDEE TEAMWORK ASSESSMENT INSTRUMENTS

TIDEE assessments were developed as part of a package of assessments for capstone design courses [6, 31]. For teamwork, four assessments were developed to elicit evidence that teams can *'display valued individual and joint contributions, supportive relationships, and well-developed team processes as they synergistically achieve more than is feasible individually.'* Three assessments are designed for formative use and one for summative use.

The four teamwork assessments were built upon twelve performance factors drawn from the teamwork literature [6]. As shown in Table 1, these factors are classified into four general areas: (1) team relationships/climate, (2) joint work/achievements, (3) member/individual contributions, and (4) team information/communication. The twelve factors are used to prompt student responses in all of the teamwork assessments, but separate assessment scores are not provided for each factor at this time. The twelve performance factors were selected to satisfy the needs of three stakeholder groups: students (e.g., workload, work quality, communication, and team climate), instructors (e.g., conflict resolution and project management), and industry (e.g., work quality, stakeholder communication, and knowledge assets). Together, these performance factors paint a broad, practitioner-

Table 1. Performance factors monitored by TIDEE teamwork assessment instruments

Category	Performance Factors
Team Relationships	**Inclusive Climate**: Building an inclusive supportive climate for all members. **Member Commitment**: Gaining buy-in and interdependence of all members. **Conflict Resolution**: Resolving conflicts to enhance teamwork.
Joint Achievements	**Goal Establishment**: Establishing shared team goals. **Planning and Management**: Managing tasks to achieve team goals. **Joint Work Products**: Producing competent consensus outputs.
Member Contributions	**Work Allocation**: Allocating responsibilities fairly to members. **Performance Quality**: Achieving quality work from all members. **Member Growth**: Facilitating team member growth.
Team Information	**Internal Communication**: Achieving effective in-team communication. **Stakeholder Communication**: Managing other stakeholder communication. **Knowledge Assets**: Building shared knowledge assets.

centered definition of issues teams need to address to be successful.

The formative assessments—Team Contract, Team Member Citizenship, and Team Processes—are used to scaffold students' learning of teamwork essentials and development of their teamwork skills. The summative assessment—Teamwork Achieved—probes students' knowledge and behaviors regarding individual member contributions and team processes employed for effective team performance. This assessment gathers evidence to document students' understanding of teamwork, evidence of teamwork performance, and new knowledge gained about team performance.

The contents of the teamwork assessments are presented briefly in the following paragraphs and are shared in full on the TIDEE website [31]. Because the Team Member Citizenship assessment and its scoring rubrics were implemented early in pilot testing, it is the focus of discussion in this paper. Although the Team Member Citizenship assessment is normally used second in order, it is discussed fourth in this paper because it is the basis for the remainder of the paper.

3.1 Team contract assessment

Team Contract is the first of the formative teamwork assessments. The Team Contract exercise provides a forum for students to discuss and negotiate consensus expectations in terms of team climate, joint work, individual work, and information management. Outcomes of this assessment include: written documentation of the team's operational plan, understanding of differences in member perspectives about teamwork, and verbal commitments of members to perform specified roles. Students also receive Team Contract feedback to help them improve their understanding of teamwork and their plan for operating their team. A scoring scale for the assessment defines five levels of performance for each of the five categories of team performance: team relationships, joint achievements, member contributions, team information, and roles and responsibilities. The instructor rates the team's contract based on the established scoring rubric and provides written feedback to guide team improvement. The rubric's delineation of different levels of performance helps students see how to improve their contract from its present state. In addition to written feedback, instructors may also meet with teams to discuss their contracts, probe misunderstandings, or give additional feedback on issues of importance to the team.

3.2 Team processes assessment

Another formative TIDEE assessment is the Team Processes instrument. This assessment may be completed by each person (individually), as a team, or as a combination of the two. First, students rate the importance and perceived level of their team's execution of twelve team processes (aligned with the twelve performance factors for teamwork). Then they describe a process they perceive to be strong, and they describe how to improve a process they deem to be less effective. If they complete the assessment individually, a subsequent discussion of similar and different perceptions will increase their understanding and their commitments to good team processes. If they complete the assessment as a team, their discussions while completing it will accomplish much of the same results. The instructor reviews the submitted assessments and uses a rubric to distinguish different levels of metacognition demonstrated by discussions of the strong and weak team processes. The instructor also provides written feedback to suggest useful steps the team can take to sustain and improve team processes.

3.3 Teamwork achieved assessment

The Teamwork Achieved assessment is designed for summative use, normally at the end of a project experience or academic term. This assessment documents the individual student's understanding of teamwork, perceptions of performance, and growth achieved through a team project. The Teamwork Achieved assessment begins with the student rating the team's present performance state by selecting a descriptor of teamwork stages adapted from Dominic et al. [7]. Next the student identifies how perceived importance of member contributions to team success have changed, followed by rating each team member on each of the same contributions. This is followed by an estimate of each member's percent overall contribution to the project. Students are then prompted to give a brief performance summary for each member, which gives supporting evidence for member ratings as well as an opportunity to cite valued aspects of each person's performance. Finally each student is asked to select and describe a team process that has effectively supported team performance, explaining how it has added value and how it will be useful in the future.

The instructor reviews each student's Teamwork Achieved assessment responses, but also sees comparisons of teammate responses that shed light on team development and individual contributions. Member performance summaries reveal specific contributions of each member and how they impacted the team. The instructor scores a student's teamwork achievements based on peer responses (ratings and performance summaries) and the students' own descriptions of an effective team process (specifics, application, and extension).

3.4 Team member citizenship assessment

Table 2 summarizes details of the remaining formative teamwork assessment—Team Member Citizenship—which is normally implemented (perhaps multiple times) after the Team Contract assessment. The Team Member Citizenship assessment focuses on contributions of individual members in support of the overall team effort. It begins with each person rating the importance of

Table 2. Summary of Team Member Citizenship assessment

Task Name	Items	Type	Instructions
Importance of Contributions	12 (3 ea. in 4 areas)	Selected response (3-point scale)	Rate each type of member contribution on its importance to team success.
Member Contributions	12 for each member	Selected response (5-point scale)	Rate each team member on contributions of the type listed for making the team effective.
Effectiveness	2 for each member	Numeric score (%)	Identify relative contributions of each team member to project achievements.
Member Strength	1 for each member	Open-ended response	Select (from list) an area of strength; describe it to show your understanding of the strength and its benefits to the team.
Member Coaching	1 for each member	Open-ended response	Select (from list) an area to improve; describe a desired state and recommended actions to achieve this new improved state.

Table 3. Scale for rating members on 12 types of contributions

Score	Scale Definition
5: Extraordinary*	Models ideal professional responsibility; consistently exceeds expectations.
4: Very Good	Faithfully meets expectations; does not fail without a compelling excuse.
3: Good	Usually meets expectations; occasionally allows failure to occur.
2: Fair	Occasionally meets expectations; too frequently fails to perform as expected.
1: Poor*	Rarely meets expectations; consistently is unreliable or performs inadequately.

* Requires written justification.

twelve types of team contributions that map to the performance factors in Table 1. The rating is on a three point scale (low, medium, and high importance). Students then rate each team member (including self) relative to these contributions using the five point scale presented in Table 3. Each member is also rated on overall time and value invested in support of the project. Finally peer feedback is written to each team member—on both a strength and an area to improve. The respondent describes a strength of each team member and provides an explanation of the benefits of this strength to the team. Additionally, each team member provides coaching with respect to an area that needs to be improved, describing the envisioned performance along with suggestions for achieving the improvement.

Team members receive multifaceted formative feedback on their Team Member Citizenship assessment responses. First, members see how their ratings of importance on twelve different contributions compare to the team as a whole; this can help them calibrate their own valuing of attributes and contributions within the team. They also receive summarized scores on their own contributions so they see how their contributions are perceived by others—both on specific types of contributions and their overall investment. The peer feedback on an area of strength helps members see which of their contributions are valued most by other members and why; this provides encouragement and helps students sustain good performances. The peer coaching helps each member understand what other members would like to see in their contributions, and they benefit from others' ideas for achieving the desired performance.

The instructor also provides feedback to each

member—first on their own coaching of others, then on other issues related to member contributions. The instructor scores each student's analysis of strengths and coaching of improvements based on evidence of the coach's understanding of contributions and their ability to coach others. The scoring rubrics for Team Member Citizenship, shown in Tables 4 and 5, provide the basis for scores related to students' understanding of desired teamwork and their abilities to relate it to team productivity and specific actions. The combination of self-assessment, peer-assessment, and instructor feedback helps students learn about desired team citizenship and how to better achieve it.

3.5 Web-based support

The TIDEE assessments have been implemented in a secure, web-based environment [31] that supports varied uses of the assessments in different course settings. The site contains assessment instruments, instructor and student interfaces, data archives, data processing, and reporting functions. The instructor specifies the assignment by indicating which students are to receive the assignment, if it is to be completed by individuals or by teams, the due date for student completion of the assignment, and the due date for instructor feedback. Students complete the assignments inside or outside of class, depending upon the instructor's approach to integrating it with class instruction.

Students complete assessment assignments online and receive feedback from the instructor and peers online. Instructors use online scoring rubrics and prompted comment boxes to provide individual or team feedback on the assignment. The web system automates data compilation for instructor and student viewing. This is particularly

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Table 4. Scoring rubric for student explanations of team member strengths

	Scoring Scale for Member Strengths				
	1 Novice	2 Beginner	3 Intern	4 Competent	5 Expert
Understanding of strengths	Misunderstood or unable to explain the strength.	Little understanding; little attempt to explain the strength.	Moderate grasp of the strength; some relevant evidence.	Credible grasp of strength; good list of evidence.	Impressive grasp; insightful description of evidence.
Benefits to team	No mention of benefits.	Casual mention of benefits; minor encouragement.	Moderate mention of benefits; some encouragement.	Clear mention of benefits; helps motivate future use.	Insightful description of benefits; guides and motivates use.

Table 5. Scoring rubric for students coaching on member contributions

	Scoring Scale for Member Coaching				
	1 Novice	2 Beginner	3 Intern	4 Competent	5 Expert
Opportunity	Vague description of opportunity; no details.	Weak description of opportunity; few details.	Okay description of opportunity; some general details.	Good explanation of opportunity; some specific details.	Superb explanation of opportunity; insightful details.
Suggestions	No suggestions or useless steps; none to implement.	Mostly vague steps; most are difficult to implement.	Reasonable steps; some possible to implement.	Clear, strong plan; most steps possible to implement.	Impressive plan; steps clear, likely to be implemented.

valuable in the Team Member Citizenship assessment where the web system computes statistics about responses from all participants and provides collated results for each team member.

The assessment cycle is complete when students log back into the system to read feedback from the instructor (and their anonymous team members, in the case of Team Member Citizenship). Through their feedback, faculty can demonstrate empathy with regard to project challenges, set the stage for an individual or team discussion about critical issues, provide guidance on project management, and plan interventions when necessary. Researchers can anonymously access data transferred between students and instructors. In addition, the web system administers post-assessment surveys to instructors and students about assignment quality and value. Information maintained by the system can be used for grading, prompting instructor feedback, planning individual or team interventions, making adjustments to formal class sessions, and preparing documentation for curriculum review and accreditation. Researchers can use information for testing the assessment instruments and for answering educational research questions.

4. IMPLEMENTATION AND TESTING METHODOLOGY

4.1 Implementation

The web-based TIDEE teamwork assessments were pilot tested with collaboration from engineering design educators at six diverse institutions in the 2008–2009 academic year. Each participating institution—Washington State University, University of Idaho, Seattle University, Rose-Hulman Institute of Technology, Smith College, and LeTourneau University—provided data of one or more of the types described below. The participating institutions have educational missions that include: doctoral degree granting, masters degree granting, technical education, and baccalaureate education. Each participating institution is represented on the project leadership team or as a consultant to the project developing the TIDEE assessments. In most cases, the capstone design instructor using TIDEE assessments was familiar with the assessment development process and the instruments themselves.

Implementation of the Team Member Citizenship assessment varied by institution and by instructor during the pilot testing. This approach ensured that a range of facilitation strategies would be employed to test the instruments in conditions realistic to a range of capstone design courses. Participating capstone design faculty who were not part of the TIDEE development team or consultants to the project were briefed by their local TIDEE project representative prior to using assessments. Briefings included discussion of the intent of the assessments, possibilities for their use in class, anticipated benefits from the assessments, and how to access and use the web-based system. In order to encourage participation, collaborating faculty were given flexibility in choosing which assessments they would use and in what term they would use the assessments. Stipends were provided as incentives for fulfilling commitments to administer assessments and provide requested data.

Capstone design course test sites for the assessments were quite varied. Students in the targeted capstone design classes represented a broad set of disciplines, including engineering (bioengineering, mechanical engineering, electrical engineering, civil and environmental engineering, chemical engineering, agricultural and biological engineering, materials engineering, and general engineering), business (marketing, management information systems, entrepreneurship, and accounting), and sciences (mathematics, physics, chemistry). Project types included client-sponsored, student-initiated, design competition, entrepreneurial, community-service, and international development. Additionally, project duration varied (one semester, two semesters, two quarters) and team size varied (3–9 members).

Each of the four teamwork assessments was used by two or more instructors. All instructors assigned the assessments for completion on the TIDEE website, although some also used hard-copy assessment materials. Most participating instructors chose to use the Team Member Citizenship assessment because it had received the most development work, was most familiar to TIDEE collaborators, and was highly valued for its ability to coach student improvement. As a consequence of this choice, findings and analysis provided in this paper are focused exclusively on the Team Member Citizenship assessment.

4.2 Testing methodology

Pilot testing of the Team Member Citizenship assessment sought to evaluate this instrument broadly for its practicality and ability to provide value to users involved in the capstone design course: students and faculty. Specifically, data collection addressed the following questions:

1. To what extent does the Team Member Citizenship assessment provide teamwork performance results that match past research and expectations?
2. To what extent do the Team Member Citizenship assessment design and scoring rubrics support reliability across instructor scoring?
3. To what extent are students and instructors (users) satisfied with the Team Member Citizenship assessment?

Data used to address these questions consists of student inputs to the Team Member Citizenship assessment, instructor ratings and feedback on student work, inter-rater reliability scoring results, and surveys conducted with students and instructors who participated in the Team Member Citizenship assessment administrations. Not all of these data types were available from all participating institutions at the time of this writing. Each type of data is described below.

4.3 Alignment of data with expectations

Data captured by the web-based assessment system was used to explore how Team Member Citizenship assessment results matched expectations. Data gathered included: (1) student perceptions of the importance of twelve types of team member contributions, (2) self and peer assessment of performance in the twelve contribution areas, and (3) student performance in the assessment as rated by the faculty. Data were collected from the institutions that obtained and submitted enough consistent and complete data for analysis. These included University of Idaho (UI), Washington State University (WSU), Rose-Hulman Institute, and Smith College. A small number of student records that had incomplete data were eliminated from the analysis. The data were obtained from two different assignments (or classes) for each UI, WSU, and Rose-Hulman. Data from Smith College reflects responses for one class. There were 126 students and 32 teams participating in all.

Student response data when rating themselves and their teammates for each of the twelve contribution items was disaggregated between self-ratings and peer ratings. That is, each individual's rating was aggregated and averaged to reflect an overall self-rating (mean self-rating for each item by institution). Likewise, each individual's rating of their teammates was aggregated and averaged to reflect an overall peer-rating mean for each item, by institution. The idea behind this strategy was suggested by Miller and Cardy [32] who found consistently higher ratings of self versus peers in appraisals of team performance. For this work, the sample size for the self-rating means is the number of students for each institution. The sample size for the peer rating means is much higher, as this reflects the total number of peer ratings (minus the self-ratings). With team sizes ranging from 2 to 9 across institutions, aggregating across peers and the number of teams substantially increases the sample size.

Data from the effectiveness measures (estimates of time invested by each member of the project and the value added to the project by each member) were disaggregated by self and peer ratings. The rationale for this course of action was the same as that offered for the student ratings for team effectiveness for the twelve team contribution items. As anticipated, self-rating means tended to be higher than for peer-rating means. This was true across institutions. For each institution the self-rating means were nearly identical for the estimates of percentage of time devoted to the project and value added. The same was found for value added estimates.

4.4 Inter-rater reliability

To provide an estimate of scoring consistency for the Team Member Citizenship assessment, a small inter-rater agreement study was conducted. For this study, multiple people scored the same student work to determine scoring agreement. To this end, four individuals (two faculty members and two graduate students) were provided training in the use of the scoring criteria for student

responses to the Team Member Citizenship assessment. The training included practice scoring of student work, score comparisons across raters, and time for discussion and justification of scores. Once sufficient understanding of the scoring criteria and its application was obtained, the four scorers independently scored work from a sample of 20 students, whose work represented a cross-section of performances. Percent agreement statistics were computed for each factor in the scoring rubric.

4.5 User satisfaction

User satisfaction was explored for both students and instructors involved with the Team Member Citizenship assessment. After the assessment assignment was completed by students and scored by the instructor, a brief questionnaire was administered to a sample of students (n = 62) asking for feedback regarding their perceptions of the usefulness of the Team Member Citizenship assessment. The questionnaire contained three items asking students to rate:

(a) their perceived estimates of the accuracy of instructor feedback,
(b) personal value derived from using the assessment instrument, and
(c) added-value the assessment provided their to project work.

Response items were based on a 5-point Likert scale with the following anchor labels: (5) very accurate/very valuable, (4) mostly accurate/generally valuable, (3) somewhat accurate/somewhat valuable, (2) mostly inaccurate/little value and (1) very inaccurate/no value. Students were also asked to estimate the amount of time they invested to complete the assessment task.

5. RESULTS

5.1 Alignment of data with expectations

Mean student responses to the importance of various member contributions to team success ranged from the mid-2s to 3 across institutions. The low mean was 2.3 for the item 'documents achievements well' to a high of 3.0 for the item 'delegates/completes tasks, as needed.' The student ratings suggest that across institutions, students view the 12 team member contributions listed in this part of the assignment as moderate to high in importance for team success. Table 6 provides the means and standard deviations for each item by institution.

From this initial data analysis, it is observed that students consistently undervalue documentation. It is clearly not a surprising insight that students do not like to document their work, but it is important to see that this expectation (and experience) matches the assessment data. Additionally, the other aspects of communication (strives for fully informed members and communicates well with stakeholders) were generally rated lower than other contributions. One interpretation of this is that students have not yet established the need for high quality documentation because they lack experience. These data trends are observed and form the basis for more focused exploration that can improve teamwork in the areas of greatest need.

As anticipated from Miller and Cardy [32], mean self-ratings tended to be higher than mean peer ratings across items and institutions. For both ratings, the magnitude of the mean ratings ranged from the high 3's to low 4's. This suggests that individual appraisal of self and peer contribution to the team can be classified as 'good' to 'very good.' Table 7 provides the means and standard deviations for self and peer ratings, respectively, for each contribution item by institution.

Students' explanations of member strengths and areas to improve provided additional insights into ways the Team Member Citizenship assessment fit expectations. The following comments reflect the kind of feedback provided by students. The first comment is a self-appraisal while the second comment is an appraisal of a teammate. Note that criticisms and ways to improve as well as compliments can be found in both self-appraisals

Table 6. Item means and standard deviations for student ratings of importance

Member Contributions/Actions	Institution A N=31		Institution B N=51		Institution C N=20		Institution D N=24	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
1. Engages members with respect	2.7	0.5	2.8	0.4	2.7	0.6	2.7	0.5
2. Commits, encourages involvement	2.7	0.5	2.7	0.4	2.6	0.5	2.7	0.6
3. Resolves conflict constructively	2.7	0.5	2.7	0.5	2.8	0.4	2.6	0.5
4. Helps establish shared goals	2.7	0.5	2.7	0.5	2.5	0.6	2.5	0.5
5. Follow plans to achieve team goal	2.8	0.4	2.8	0.4	2.7	0.5	2.7	0.5
6. Works synergistically with others	2.7	0.5	2.6	0.5	2.6	0.6	2.4	0.5
7. Delegates/completes tasks, as needed	2.8	0.4	2.8	0.4	2.8	0.5	3	0.2
8. Performs competently to team standards	2.8	0.4	2.6	0.5	2.8	0.4	2.8	0.4
9. Enables development in self and others	2.4	0.5	2.4	0.6	2.5	0.6	2.2	0.6
10. Strives for fully-informed members	2.6	0.6	2.6	0.5	2.6	0.7	2.5	0.5
11. Communicates well with stakeholders	2.5	0.5	2.7	0.5	2.8	0.4	2.6	0.5
12. Documents achievement well	2.3	0.5	2.6	0.6	2.6	0.7	2.5	0.7

Table 7. Means and standard deviations for self-ratings & peer-ratings of member contributions

Member Contributions/Actions	Institution A				Institution B				Institution C				Institution D			
	Self N=31		Peer N=86		Self N=51		Peer N=263		Self N=20		Peer N=60		Self N=24		Peer N=69	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
1. Engages members with respect	4.6	0.6	4.6	0.5	4.5	0.6	4.0	0.7	4.0	0.8	3.9	0.9	4.4	0.7	4.2	0.8
2. Commits, encourages involvement	4.1	0.7	4.2	0.7	3.9	0.7	3.8	0.8	4.1	0.7	3.9	0.8	4.0	0.7	4.0	0.8
3. Resolves conflicts constructively	4.3	0.6	4.4	0.6	3.9	0.7	3.8	0.7	4.1	0.8	3.9	0.9	4.3	0.7	4.0	0.8
4. Helps establish shared goals	4.2	0.6	4.1	0.9	3.9	0.7	3.8	0.8	4.3	0.7	4.0	0.7	4.3	0.6	4.0	0.8
5. Follow plans to achieve team goal	4.1	0.6	4.1	0.7	3.9	0.6	3.9	0.7	4.1	0.8	3.9	0.8	4.2	0.7	4.2	0.9
6. Works synergistically with others	4.2	0.6	4.2	0.6	3.9	0.8	3.8	0.8	4.3	0.6	4.1	0.8	4.2	0.6	4.0	0.9
7. Delegates/completes tasks, as needed	4.1	0.8	4.1	0.8	3.9	0.7	3.8	0.8	4.2	0.6	3.9	0.8	4.0	0.8	4.1	0.8
8. Performs competently to team standards	4.3	0.6	4.3	0.6	4.0	0.7	4.0	0.7	4.3	0.7	4.0	0.9	4.6	0.7	4.3	0.8
9. Enables development in self and others	3.9	0.6	4.0	0.7	3.8	0.7	3.7	0.8	4.0	0.7	3.9	0.9	4.1	0.8	4.0	0.8
10. Strives for fully- informed members	4.1	0.9	4.0	0.9	3.9	0.7	3.8	0.8	4.1	1.0	3.9	1.1	4.4	0.6	4.3	0.6
11. Communicates well with stakeholders	3.7	0.8	3.8	0.9	3.7	0.7	3.7	0.8	3.8	0.9	3.9	1.0	4.1	0.8	4.1	0.6
12. Documents achievement well	3.7	1.0	3.7	1.0	3.6	0.9	3.8	0.8	3.8	0.9	3.6	1.0	4.4	0.7	4.2	0.7

and appraisals of peers. Criticisms, however, are more prevalent in the comments about peers.

Strength, self-appraisal: *My strong communicative skills allow me to convey information to stakeholders effectively and appropriately. My oral skills are highly developed in business and stakeholders feel comfortable speaking with me, gaining opportunities we may have not had without such comfort. My communicative skills impact the team in providing a liaison between stakeholders and ourselves.*

Coaching, peer-appraisal: *As the team leader, User #1 appears to take on much of the work load himself without allowing the rest of the team to contribute. While he does not appear to have any problem doing so, it does not allow the rest of us to contribute as much to the project as we would otherwise be willing to. Being able to share in the work equally would allow each of us to have an equal understanding of the problem and our solution. User #1 should allow me and User #2 to take a more active role in some of the work that is being done.*

Faculty rating of students' written explanations of member strengths and coaching for improvement provide additional evidence that the assessment provides results as expected. Across institutions and items the means of faculty ratings ranged from a low of 2.2 for the member coaching 'suggestions' item, to a high of 3.8 for the member strengths 'benefits to team' item. These ratings place teams in the beginning to competent scale range. Faculty from all institutions tended to provide higher ratings for the member strength

items. Table 8 provides the means and standard deviations for faculty ratings of student responses by institution. The reliability of these scores across raters is addressed in the subsequent section.

The data seems to match the intuitive perception of expected student performance in assessment that students will perform better in reporting observations and struggle with higher level critical thinking. Identifying a strength and an opportunity for peer and self improvement are examples of directly reporting upon observations. In these areas, students scored better than in identifying the benefit of that strength and suggesting a path to realizing the improvement which require creativity and critical thinking.

The following written responses provide examples of the kinds of faculty comments provided to students, comments that reflect the formative nature in which the Team Member Citizenship assessment was used.

Be sure when coaching someone you don't send mixed messages. For example: you identify User#1's strength as showing initiative to learn new things and then say her weakness is not showing initiative when she could have in seeking contacts. This could lead to confusion, so be very clear in making distinctions.

Excellent job. I noticed you were more critical of yourself than others. It's okay and beneficial to enjoy the gifts and strengths of the team you've been given. I have been very impressed with the quality of your contribution to your group.

Table 8. Instructor means & standard deviations for scoring strengths & coaching by institution

	Institution A N=31		Institution B N=51		Institution C N=20		Institution D N=24	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Member strengths								
Understanding of strength	3.7	0.5	3.2	0.8	3.1	1.0	3.1	0.7
Benefits to team	3.8	0.5	2.9	0.7	3	0.9	2.7	0.8
Member coaching								
Opportunity	3.7	0.7	3.1	0.9	2.9	0.9	2.8	1.0
Suggestions	3.6	0.7	2.7	0.7	2.6	0.6	2.2	0.9

Table 9. Rater pair number (and percent) for each scoring difference

Difference	Rater Pairs*						Mean
	1–2	1–3	1–4	2–3	2–4	3–4	
0	4 (20%)	8 (40%)	5 (25%)	11 (55%)	14 (70%)	12 (60%)	9 (45%)
± 1	15 (75%)	11 (55%)	15 (75%)	8 (40%)	6 (30%)	8 (40%)	10.5 (52.5%)
± 2	1 (5%)	1 (5%)	0	1 (5%)	0	0	0.5 (3%)
± 3	0	0	0	0	0	0	0
± 4	0	0	0	0	0	0	0

*Raters 1 and 2 are previous capstone design instructors. Raters 3 and 4 are engineering teaching assistants.

5.2 Inter-rater reliability

Comparing ratings given by different raters for the same student work provides insight about the consistency with which the assessment gives feedback to students. Table 9 presents results by different combinations of rater pairs for the four raters scoring Team Member Citizenship responses. Cells in the table present (by rater pairings) the number and percent of ratings that differed by 0, 1, 2, 3, and 4 points (on a 5-point scale). For instance, raters 1 and 2 (both capstone design instructors) agreed on four of the twenty scores they separately gave to student responses. Their scores differed by 1 point on fifteen additional student responses scored, and they differed by 2 points on the one remaining student. Averaging the point differences for the six rater pairs, 45% were in agreement, 52% differed by 1 point, and 3% differed by 2 points. These initial rater agreement data provide tentative information about scorer agreement, suggesting that the Team Member Citizenship assessment can be scored reliably by individuals receiving training.

5.3 User satisfaction

User satisfaction is indicated by viewing student and instructor rating summaries. Figures 1 through 3 provide descriptive data and graphic representation of student responses on assessment accuracy, personal value, and team value, respectively. As shown in Fig. 1, a substantial number of student participants rated the Team Member Citi-
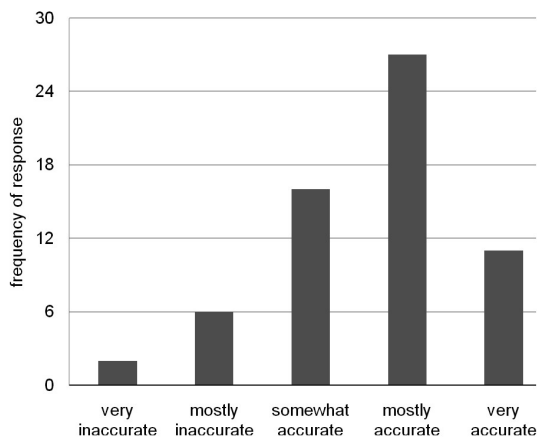
zenship assessment as mostly accurate or very accurate. Specifically, out of 62 respondents, 38 (61%) students perceived instructor feedback as very accurate or mostly accurate (Fig. 1), 30 (48%) students found the exercise to be personally very valuable or generally valuable (Fig. 2), and 27 (44%) students found the exercise to be very valuable or generally valuable to the team (Fig. 3).

Students were also asked to provide additional comments about the assessment. While only 25 of the 62 participating students chose to provide a comment, the feedback provided insight into the personal value derived from the assessment experience, and in a few instances, suggestions for improving the activity. The following comment
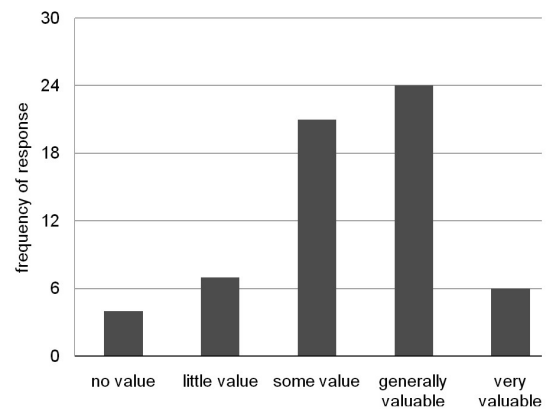
Fig. 2. Student perception of personal value derived from the assignment (N = 62).

Fig. 1. Student perception of the accuracy of instructor feedback (N = 62).
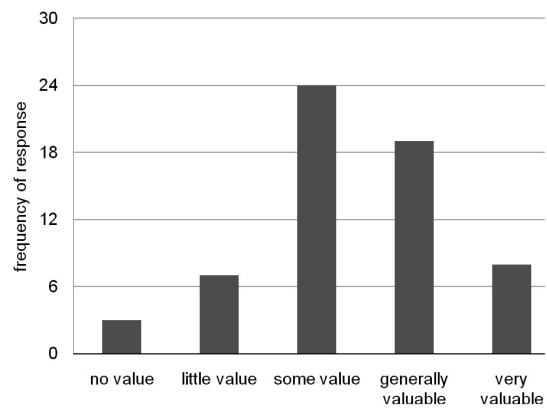
Fig. 3. Student perception of team value derived from the assignment (N = 62).

represents the kind of self-reflective feedback received from students:

> I believe this assignment was very good overall; it inspired confidence in what I was doing well and allowed me to see what else I needed to do in order to create a better team environment. It took me a while to be critical of not only everyone else but also of myself; it definitely made me think and consider what needed to be done.

It is also important that members of industry find value in the exercise and feedback. To date, no direct feedback has been collected from industry, but industry surveys on the relative importance of various teamwork activities and skills were used to develop the instruments [11].

6. DISCUSSION

The findings reported here are limited to the Team Member Citizenship assessment, only one of four in the TIDEE set of assessments for teamwork. Additional limitations in data interpretation include: the small sampling of data, the subjectivity of making ratings, types of data available, lack of details on each assessment implementation, and lack of information about variables that affect team performance and engagement for both students and faculty. Thus, the results are considered preliminary but still useful for judging the merits of the Team Member Citizenship assessment.

It is clear that the specifics of implementation and facilitation of assignments are important variables in determining the overall validity of this assessment instrument. While best practices in facilitation have not yet been determined from experimental results, McCormack et al. [33] recently reported preliminary data on types of responses obtained from students and practical issues to be considered for effective implementation of this and similar assessments. Factors affecting successful implementation included: (1) timing of the assessment, (2) preparation of instructors and students, and (3) implementation of specific activities associated with the assessment. In addition, the authors recommended that sufficient orientation be done to ensure that students understand how the teamwork assessments align with successful completion of their design project and future professional practice.

Because ratings by students and faculty are subjective, they are fraught with variability. What constitutes a 1, 2, 3 (or more, depending on the item) is defined in the assessment but also subject to interpretation. Certainly, accuracy and consistency can be improved with proper training and standardization on best practices in facilitation. The inter-rater reliability data in this paper suggests that minimal training in use of scales gives consistent results. Data was not readily available to distinguish, by institution, whether students received training or if their score ratings were monitored.

Disaggregating students' peer and self ratings and attributing these ratings cleanly to actual performance have and continue to challenge researchers investigating team work. Ratings of other members on the team are often dependent on factors other than performance, and ratings of self are often higher than those of fellow team members [34]. Thus, available statistical procedures for data analysis are sometimes limited in appropriately capturing information from self and team member ratings of each other. For this limited pilot, descriptive statistics were relied upon to portray sample data characteristics. In addition, for the member contribution ratings, self ratings were separated from peer ratings. A similar strategy was employed by Miller and Cardy [32]. In this way, if differences between self and peer ratings exist, they can be detected. A limitation of this approach, however, is that any team dependence of ratings is not accounted for when separating each individual's self rating from the corresponding peer ratings.

As mentioned, faculty collaborators were given maximum flexibility for implementation. This was done to gain their buy-in and participation. Additional data regarding implementation of the assessments are being collected and will be analyzed in coming months. Initial feedback and discussion with collaborators has revealed that implementation of the teamwork assessments varied with the instructional practices of the faculty members, size of the program, and type of capstone course, findings similar to that of McCormack et al. [33]. At this time however, reasonable statements about implementation differences between programs and what influence this might have on student performance are not possible from the current data.

There are several ancillary variables that mediate the adoption of teamwork assessments for which data was not collected in this study. Thus, statements about the influence of these variables on team-based activities and assessments are unwarranted. For instance, Freeman and McKenzie [35] reported that cost savings and efficiencies provided by on-line assessments, particularly in large classes, seem to improve student performance and engagement. In addition, the work of Williams, He, Elger, and Schumacher [36] drew a strong connection between peer evaluation and student motivation to perform in team-based projects. With regard to faculty, Moskalski [37] found that prior experience with team-based activities was a predictor of whether and how faculty would institute team-based activities in their classes. Finally, while the previous findings deal with team-based activities and assessments in undergraduate engineering courses, no study could be found in the literature that dealt specifically with mediating variables for team-based assessments in capstone design engineering courses.

7. CONCLUSIONS

This paper describes the rationale for the TIDEE teamwork assessments, the contents of the assessments, and a review of data and results to-date for the Team Member Citizenship assessment. Preliminary findings support the use of the TIDEE teamwork assessments and give empirical support for the Team Member Citizenship assessment. Student feedback indicates that students were engaged in the assessment process and found value in this assessment activity. Furthermore, the data suggests that instructor feedback to students was valued by students, affecting their subsequent performance. Students saw value in the self- and peer-evaluation component of the Team Member Citizenship assessment as means to improve self, team member, and subsequently, team performance. The inter-rater reliability study showed that rating of student work can be performed consistently across instructors for the Team Member Citizenship assessment.

The findings taken together provide an emerging picture of a carefully developed collection of team based assessments for capstone engineering design course work. The findings further suggest that these assessments hold promise for developing student teamwork skill and competency important for engineering work. Planning for more comprehensive studies with more uniform implementation across programs, sizable datasets for all assessments, and provisions for controlling variables such as motivation are underway within the TIDEE consortium.

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Denny Davis is professor of Bioengineering and Director of the Engineering Education Research Center at Washington State University.

Michael Trevisan is professor and interim chair of the Department of Educational Leadership and Counseling Psychology, and Co-Director of the Learning and Performance Research Center at Washington State University.

Howard Davis is clinical assistant professor in Bioengineering at Washington State University.

Robert Gerlick is graduate research assistant in Engineering Education at Washington State University.

Jay McCormack is assistant professor of Mechanical Engineering at the University of Idaho.

Steven Beyerlein is professor of Mechanical Engineering at the University of Idaho.

Phillip Thompson is associate professor and chair of the Department of Civil and Environmental Engineering at Seattle University.

Susannah Howe is the Design Clinic Director in the Picker Engineering Program at Smith College.

Paul Leiffer is professor and chairman of the Department of Engineering at LeTourneau University.

Patricia Brackin is professor of Mechanical Engineering at Rose-Hulman Institute of Technology.